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Analysis of Sediment Transportation along the Seaport River at Niaga Brondong in Lamongan District

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Abstract- Estimating the amount of sediment along the coastline of the Brondong seaport under various conditions is very important to know. By knowing the amount of sediment transport along the coastline, the causes of the sediment can be identified. The existence of coastal structures will cause sediment on one side and cause erosion on the other. Brondong Beach has several problems that need to be addressed immediately, namely as a port gate, so that there is no silting in the port pool. Observations were made at 7 points, namely 4 points (point 1 to point 4) west of the mouth of the Brondong river and 3 points east of the river mouth (point 5, point 6 and point 7). Based on the analysis of the calculation of the amount of sediment transport based on the CERC method, the value of sediment transport to the east at point 1 is 449.971,2 m3/year, point 2 = 514.252,8 m3/year, point 3 is 598.971 m3/year, point 4 = 578.534, 4 m3/year, point 5 = 578.534,5 m3/year, point 6 = 642.816 m3/year and point 7 = 741.783 m3/year and the smallest sediment transport value is in point 1 with a yield value of 449.971,2 m3/year.

Keywords- *CERC Method, Sediment Transport, Niaga Brondong*

I. INTRODUCTION

The river mouth of the Niaga Brondong seaport has a fairly large river mouth. The length of the Brondong river is ± 2 km with a watershed ± 2.5 km2. The area downstream of the Brondong river is the Brondong Niaga Seaport, Lamongan District. The port has high waves. In certain months the wave height is quite large and disrupts the livelihood activities of the residents of the Brondong and surrounding areas. Waves are the main cause of sediment transportation in the litoral zone [1]. Large waves will break farther from the coast, this means that the surface zone will widen and cause increased sediment transport on the coast [2]. Changes in wave period or wave height cause the movement of sand towards the coast or the sea. The angle between the braking wave crest and the shoreline shows the direction of the movement of water in the zones and usually also indicates the direction of longshore transport [3][4]. Based on these things knowledge of the state of the wave (period, wave height, and wave direction in each season) is very necessary. Littoral transport can occur in two ways: bedload transport and suspended load transport [5][6]. Also, the study area experienced silting which could disrupt the activities and work of the fishermen around. The process of siltation or sedimentation can be caused by the high content of sediment carried by the process of transformation of water from upstream to downstream caused by land erosion.

The number of human activities along the Brondong River has an impact on the river mouth sediment volume, which is precisely in the area of the Brondong commercial port. One of the activities affecting the estuary is illegal logging at the top or upstream. This activity resulted in an erosion of the land surface along the Brondong river. The amount of sediment along the river (suspended load) will increase, causing siltation in the river mouth. Factors influencing sedimentation around the estuary are waves and currents. For example, the effect of tides on the coast or around the estuary will cause sediment deposition (small islands) that occur in the dominant direction of the movement of the series. Likewise, the construction of coastal structures such as Jetty, the breakwater, will influence the movement of sediment in one position and erosion will occur on the other side [7][8]. Therefore, predicting sediment transportation along the coast is very important to calculate the amount of sediment transport and examine the effects that are likely to occur. Brondong Subdistrict, which is mostly coastal, the livelihoods of residents are traditional fishermen. At the estuary, a Jetty will be built. The existence of the development of a sediment analysis is needed to know the amount of sediment produced.

A. Waves

Waves can generate energy to form a beach, causing sediment currents in the perpendicular direction of the coast. As well as causing forces acting on beach buildings [9]. Waves are a major factor in determining the location of ports, shipping lines, coastal planning, and so on. Therefore coastal engineers must understand the characteristics of waves and the effect on a beach structure [10][11]. The wave formula is stated as follows:

$$L_0 = gt^2/2\pi = 1{,}56\ T^2 \quad (1)$$

$$C_0 = gT/2\pi = 1{,}56\ T \quad (2)$$

$$C = L/T \quad (3)$$

with:

L_0 = deep sea wavelength (m)

C_0 = wave acceleration in the deep sea (m/sec)

T = period of waves (seconds)

B. The Dominance of River Flow at The Estuary

The type of estuary is distinguished by the amount of river flow each year so that the discharge is the main parameter for the formation of river estuaries in the sea with relatively small waves. Rivers carry a large amount of sediment transport. When the water recedes, the sediment will be pushed upwards and spread out to sea. When the water starts to rise, the flow velocity increases and a portion of the suspension from the sea re-enters the river to meet the sediments originating from the upstream.

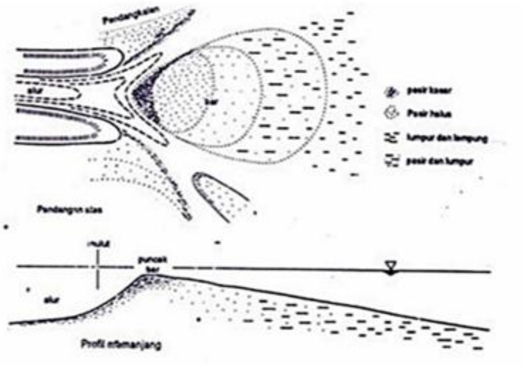

Figure 1. The Dominance of River Flow at The Estuary

C. Tidal Dominance on Estuaries

This type of estuary has a funnel or bell shape and is characterized by quite large tidal fluctuations. If the tidal height is large enough, the volume of tidal water entering the river is very large. The water will accumulate with water from the upriver. At low tide, a very large volume of water flows out over some time, depending on the type of tides. Then the current velocity during low tide is large enough and has the potential to form river mouths [12].

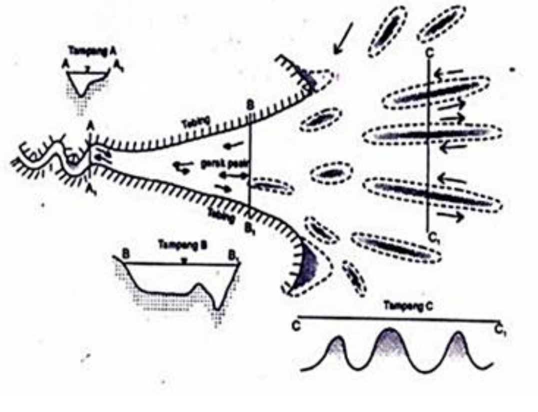

Figure 2. Tidal Dominance on Estuaries

D. Wind

The wind is an air circulation which is approximately parallel to the surface of the earth [13][14]. Measurement of wind data at sea level is the most suitable for wave forecasting. The data was obtained from BMKG (Meteorology, Climatology, and Geophysics) Perak I Surabaya in 2016-2018. The data is taken right in the area of the Brondong Sea Commerce Port estuary located at coordinates 6052'24,9 "S and 112015 '53,5" E (Google Earth). The data provided by BMKG Perak I Surabaya for this research is the average and largest daily wind speed data. Wind speed is expressed in units of Knots, one knot is the length of one minute of longitude through the equator taken in one hour, or 1 knot = 1,852 km/h = 0,5 m/sec.

E. Fetch

The fetch is the wave distance from the start of the generation which is limited by the shape of the land that surrounds the sea and has a relatively constant wind speed. The farther the distance travelled, the higher the altitude, while strong winds will produce large waves . Wind direction can still be said to be constant if the change is not more than 15o. Meanwhile, the wind speed is still considered constant if the change is not more than 5 knots (2,5 m/sec). In a review of waves at sea, fetch is limited by the shape of the land surrounding the sea, and the same direction with the direction of the wind and various angles wind. The effective average fetch value is obtained by the following equation:

$$F_{eff} = \frac{\sum X_i \cos \alpha}{\sum \cos \alpha} \tag{4}$$

with:

F_{eff}= effective average fetch

X_i = the length of the fetch segment measured from the observation point to the end of the fetch wave

α = deviation of both sides of the wind direction, using an increase of 6^0 to an angle of 42^0 on both sides of the wind direction

In the formation of deep-sea waves when fetch conditions are limited, the wind is constantly blowing long enough for the wave height to reach equilibrium at the end of the fetch, and the wave conditions are limited by the length of the wind blowing.

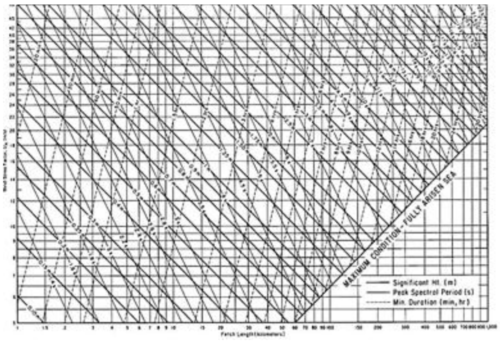

Figure 3. Wave Forecasting Charts

F. Wind Speed

Wind measurements are carried out on land, whereas the wind data waveform formula used is above sea level. Therefore we need a transformation from wind data above the study site to wind data above sea level. The wave generator formula and graph contain the variable UA, the wind stress factor which can be calculated with the wind speed. Land wind speed:

$$U_L = \text{wind speed x } 0{,}514 \tag{5}$$

Wind stress factor (wind-stress factor):

$$U_A = 0{,}71 \text{ x } U_w^{1{,}23} \tag{6}$$

Wind speed above sea:

$$Uw = R_L \text{ x } U_L \tag{7}$$

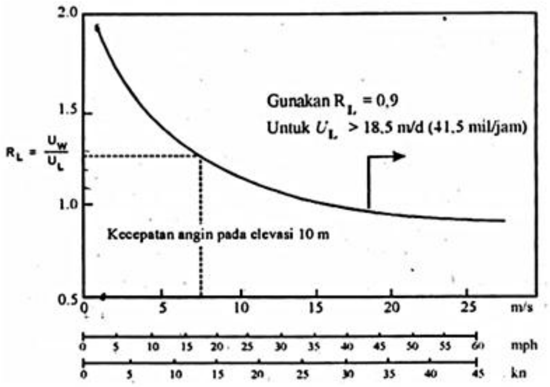

Figure 4. The Relationship Between Wind Speed at Sea and Land

Deep sea wave height:

$$H_0 = 5{,}112 \text{ x } 10^{-4} \text{ x } U_A \text{ x } F^{0.5} \tag{8}$$

Deep sea wave period:

$$T_0 = 6{,}238 \text{ x } 10^{-2} \text{ x } (U_A \text{ x } F^{1/3}) \tag{9}$$

G. Wave Refraction

Wave refraction is a change in a wave shape that adjusts to the depth contours of the ocean caused by changes in wave propagation velocity. In areas where the water depth is greater than half the wavelength, the waves will spread without being affected by the seabed. When reviewed the wave crest moves towards the coast, the crest of the wave is in a shallower water position and travels at a smaller speed. As a result, the wave crest line will try to be parallel to the contour line of the seabed. In wave refraction studies, calculations are used as follows:

$$\text{Sin } \alpha = \left(\frac{C}{Co}\right) \sin \propto_0 \tag{10}$$

$$K_r = \sqrt{\frac{\cos \alpha_0}{\cos \alpha}} \tag{11}$$

$$K_s = \sqrt{\frac{n_0 L_0}{nL}} \tag{12}$$

$$H = K_s \,.\, K_r .\, H_0 \tag{13}$$

with:

L = wavelength (m)

C = wave propagation fast

T = period of wave (s)

Sin α = angle between the crest of the wave and the contour line at the point of review

α = angle between the deep sea wave crest line and the coastline (°)

K_r = refraction coefficient

K_s = shoaling coefficient (superficiality)

n_0 = deep sea parameters

H = height of deep sea waves (m)

H. Sedimentation

Sediment transport along the coast (longshore transport) is caused by turbulent sediment when the wave breaks, then move carried by currents and waves along the coast. At some point on the coast, sediments arrive and sediments leave (transport). When the sediment transported is greater than the incoming sediment, coastal erosion will occur [15].

I. Sediment Transport Along The Coast

$$H_{RMS} = \sqrt{\frac{1}{N} \sum_{i=1}^{N} H_i^{\,2}} \tag{14}$$

$$S = A\, H_{RMS}^{\;2}\, Co\, (K_{rbr})^2 \sin(\propto_{br})\, \cos(\propto_{br}) \tag{15}$$

with:

S = amount of sediment transport for 1 year (m^3/year)

A = CERC coefficient (used) = significant wave height at sea in (m)

N = total number of waves

Co = velocity of wave propagation at sea in (m/s)

K_{rbr} = refraction coefficient on the outside of the breakzone (<1)

α_{br} = angle of arrival of wave (°)

Hb = breaking wave height (m)

J. Up-right Coastal Sediment Transportation

Sediment transport is divided into two parts, namely sediment transport heading to the deep sea (offshore) as occurs during a storm, and heading towards the coast (onshore) as occurs during waves. In calculating longshore sediment transport, the Irribaren formula is used to determine the amount of wave run-up in buildings with sloping surfaces for various types of material. Here's the Irribaren formula:

$$I_r = \frac{tg\,\theta}{(\frac{H}{Lo})^{0{,}5}} \tag{16}$$

II. METHODOLOGY

1. Data collection consisting of:
   - Wind data, wave data, tidal data, topographic maps, and bathymetry measurements
2. Conducting preliminary surveys
3. Transforming map projections, to find out the coordinates of the distribution of sedimentation points
4. Implementation of data analysis and calculation. Data analysis activity is the result of data collection and then analyzed using the CERC equation to get the amount of sediment transport.

III. DISCUSSION

Sediment transport along the coast can cause land problems such as siltation at ports and erosion. In determining this sediment transport analysis, researchers used 7 points to get more effective results for calculations using CERC.

The following is an example of a sediment transport calculation using the Contingent Emergency Response Component (CERC) method at point 1.

$H_{RMS} = \sqrt{\frac{1}{N}\sum_{i=1}^{N} {H_i}^2} = 0{,}53$

$K_{rbr} = 0{,}64$

$H_0' = K_{rbr} \text{ x } H_{RMS} = 0{,}64 \text{ x } 0{,}53 = 0{,}34 \text{ m}$

$a = \tan\frac{2\pi d}{L} = 0{,}3632$

$b = \frac{2\pi d}{L} = \frac{2x\ \pi\ x\ 2}{33{,}02} = 0{,}38$

$\propto_{br} = arc \sin\frac{0{,}3632}{0{,}38}\sin 19{,}41^o = 24{,}23$

$S = (0{,}028) \text{ x } 0{,}53^2 \text{ x } 11{,}96 \text{ x } 0{,}64^2 \text{ x } \sin(24{,}23) \cos(24{,}23)$

$S = 0{,}014 \text{ m}^3\text{/s x } (24 \text{ x } 3600 \text{ x } 31 \text{ x } 12)$

$S = 449971{,}2 \text{ m}^3\text{/year.}$

Figure 5. Location of Sediment Transport Points

The following is the calculation of sediment transport using the Contingent Emergency Response Component (CERC) method at points 1-7.

TABLE I. THE CALCULATION OF SEDIMENT TRANSPORT RESULTS

Point	H	T	L_0	C_0	α	H_{RMS}	K_{rbr}	H_0'	a	b	L	α_{br}	S
	(m)	(sec)			$(^0)$	(m)					(m)		$(\text{m}^3\text{/year})$
1	0.53	7.67	91.77	11.96	19.41	0.53	0.64	0.34	0.3632	0.38	33.02	24.2	449971.2
2	0.54	7.73	93.21	12.06	19.59	0.54	0.65	0.35	0.3553	0.37	33.83	24.7	514252.8
3	0.54	7.77	94.18	12.12	19.38	0.54	0.64	0.34	0.3553	0.37	33.83	22.8	598971.3
4	0.59	8.26	106.43	12.88	18.02	0.59	0.64	0.38	0.3386	0.35	35.64	23.3	578534.4
5	0.59	8.23	105.66	12.84	18.16	0.59	0.64	0.38	0.3386	0.35	35.64	23.3	57.8534.5
6	0.62	8.48	112.18	13.23	17.57	0.62	0.64	0.39	0.33	0.34	36.66	23	642816
7	0.69	9.14	130.32	14.26	16.59	0.69	0.64	0.4	0.2223	0.31	40.29	13.9	741783.3

Source: Research results

IV. CONCLUSION

Based on the analysis of the calculation of the amount of sediment transport based on the Contingent Emergency Response Component (CERC) method, the sediment transport value is at point 1 of 449.971,2 m3/year, point 2 = 514.252,8 m3/year, point 3 of 598.971m3/year, point 4 = 578.534,4 m3/year, point 5 = 578.534,5 m3/year, point 6 = 642.816 m3/year and point 7 = 741.783 m3/year and the smallest sediment transport value is at point 1 with the result value of 449.971,2 m3/year. At point 7, there is the largest sediment transport, so it needs serious handling. Especially in upstream areas, reforestation is necessary to reduce landslides and sedimentation.

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